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ABSTRACT

Preliminary results from a study of students' conceptions in introductory rotational physics are discussed. Analyses of data from problem solving interviews and written diagnostic tests provided evidence that many students had a poor qualitative understanding of torque. Even among students who answered questions correctly a percentage did so for inappropriate reasons. These results are consistent with the view that introductory physics students often fail to actively transform problems into physically relevant representations, but function instead at a superficial level of understanding in which their attention is focused on the more perceptually obvious features of the problem. (Author/CW)

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ABSTRACT REASONING IN ROTATIONAL PHYSICS

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ABSTRACT

Preliminary results from a study of students' conceptions in introductory rotational physics will be discussed. Analyses of data from problem solving interviews and written diagnostic tests provide evidence that many students have a poor qualitative understanding of torque. Even among students who answered questions correctly a high percentage did so for inappropriate reasons. These results are consistent with the view presented by Gray (Cognitive Process Instruction, Franklin Institute Press, Philadelphia, 1979) that introductory physics students often fail to actively transform problems into physically relevant representations, but function instead at a superficial level of understanding in which their attention is focused on the more perceptually obvious features of the problem.

Much of the recent research in physics education shows that introductory students understand less qualitative physics than had previously been realized, (Clement[1,2], Fuller, Karplus, et al[3]). Several studies have shown that the predominant method of problem solving in physics includes "formula-centered" knowledge as often as a firm grasp of fundamental concepts, (Larkin[4], Reif[5], Clement[6]).

Gray[7,8] has begun to develop a theory for why so many students retain formula 'plug-in' procedures even in situations where conceptual learning is stressed. He has demonstrated that in many cases they appear to be restrained from reaching a conceptual understanding because they are unable or unwilling to apply a transformation to a given situation. Their attention appears to be bound to preserving the superficial structure of the problem and thus they are unable to disregard or modify its perceptually obvious features.

This paper presents the results from a study on students' problem solving behavior in introductory rotational physics. A test including 10 torque problems was administered to 26 students shortly after they had completed the rotation section of a two semester non-calculus based physics course. Following the test 6 subjects were randomly selected from volunteers for paid clinical interviews in which they were given problems similar or identical to those that appeared on the test.[9] During each interview the subjects were asked to explain their reasoning in choosing the solutions for each problem. If they used a formula they were requested to show how they had chosen the appropriate parameters. All interviews were recorded on

audio tapes and later transcribed to a written protocol.

The problems given were qualitative multiple choice torque problems as shown in Fig (1). They were designed so that the relevant features of the problem such as the moment arm of a force, were not explicitly sketched, but could be inferred exactly from the graph paper background. The students were told that the rigid lever would rotate only about the pivot point P and only in the plane of the page, as if on the flat surface of a table. They were then requested to determine whether the rigid arm would rotate clockwise, counterclockwise, or not at all.

It is possible to regard as distinct the two equivalent representations corresponding to the two correct methods of solution of problems of this type. One representation (as realized in Fig (2)), is formed by constructing the 'line of action' and the 'moment arm'. The relation $T = Fx$ then provides a value for the applied torque. The other representation, Fig (3), is formed by constructing a straight line between the pivot point and the point of application of the force. The value for torque is then found by the relation $T = Fd \sin \Theta$ where Θ is the angle between the constructed line and the line of action.

In each of these representations the problem solver makes explicit the proper conceptual structure by transforming the perceptual characteristics of the given problem. In order to do this, one must ignore perceptual features and actively construct the relevant information implicitly included in the presentation of the problem.

Two problems that are of interest because of their identical conceptual representations are #4 and #7, Fig (1). These two problems were included

both in the test and in the interview problem set. The error rates for these are shown in Table (1).

Although these problems were in essence identical, 42% of the test answers on #4 differed from the equivalent answers on #7. This is evidence that many students regarded those problems as dissimilar, a view that they could not have maintained if they had constructed the representation for each problem correctly.

What criteria were students using to obtain their erroneous problem solutions? Protocols obtained from the interviews indicate that random guessing was not a major factor. When asked for justification of their answers, the subjects consistently demonstrated that they possessed a valid semi-quantitative measure for each decision, usually valid torque relations. However, the corresponding physical representation was often incorrectly specified. For instance, although on problem #7 there was a null error rate in the interview (Table 1), 83% used parameters found from the perceptually obvious features of the diagram. By coincidence, the distances evident in the diagrams were equivalent to the distances one must construct (Fig 4). Were it not for this coincidence, the error rates for problems #4 and #7 would not have differed so radically.

One protocol in particular illuminates the manner in which a perceptually fixed student uses only the features immediately evident in the diagram for his approach to problem #4. The following is a dialogue between the student and the interviewer in which the student expresses a torque formula and explains what aspects of the diagram (Fig 5) he chose for the parameters.

S: What I recall as the formula for what a torque is, the force times the distance from the pivot point times the sine of the angle... though the two forces are equal, there will be a net rotation out of this because of the fact that the distance from the pivot point is not equal and the angles between the pivot point is not equal.

I: So what would be the distances here? Let's say to F2...

S: F2, the distance would be the distance between the pivot point and this first angle on the rod (Fig 5)... Theta would be the angle between the force and the rod.

S: This was a definite different theta here. Where this force (F1) is applied (Fig 5), and it's also a longer distance <u>of the rod</u> as opposed to what F2 is applied to... (Student motions that the distance would be from the point of application of F to the pivot point <u>along the length</u> of the lever arm.)

So I would say off hand that this would have a... the net rotation would be caused by force one rather than force two. And that would cause it to rotate in a clockwise direction... around this way.

How does the ability to transform relevant aspects of a problem relate to success in physics? Scores on the torque test were correlated to course grades; a scatter plot is shown in Fig 6. A high score on the test was assurance of a high course grade as evidenced by the localization of points in the upper right corner of the plot. On the other hand, high course scores were dispersed along high and low values for test scores. This implies that being a successful student was a necessary but not sufficient condition for success on the test.

From the scatter plot in Fig 6 we can claim that the rotation test measures a skill which is critical to success in physics. People who possess this skill do well. But, the scatter plot also shows that one can do well in introductory physics without possessing this skill. This

suggests that there may be several different paths to success in introductory physics.

From the interview data we have concluded that the rotation test is a measure of how well a student can transform perceptual aspects of a problem situation for the purpose of clarifying the conceptual structure. Clearly this is an essential skill for advanced work in physics; and one we would like to see in physics majors.

Courses for non-majors seem to be structured so that students can get by without this skill. This may be entirely appropriate; however, we suspect it is more by chance than by design. We hope that the rotation test will stimulate further discussion concerning what the goals of an introductory physics course ought to be.

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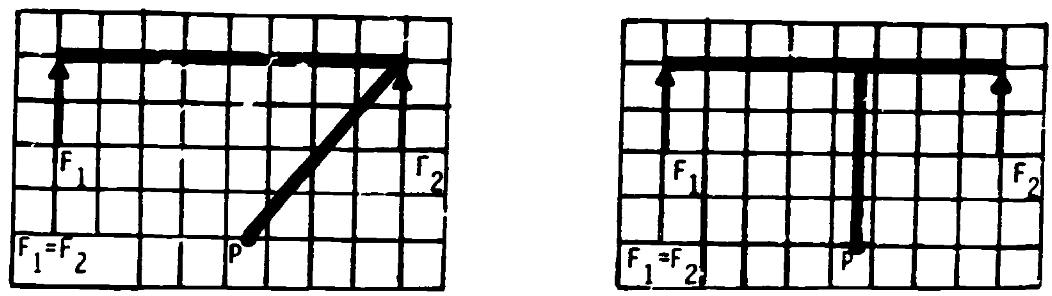
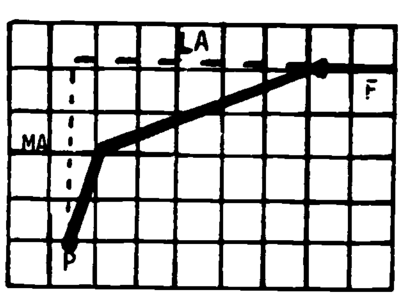
9. The average test score was 47% (correct); the average test score for the sub-group of interviewed subjects was 63% (correct).



#4

#7

Figure 1



LA = Line of Action
MA = Moment Arm

Figure 2

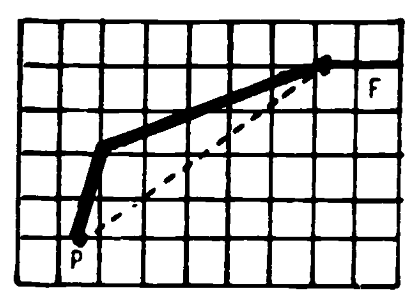
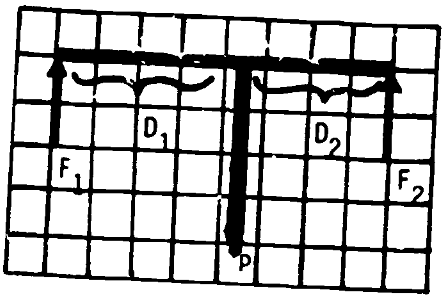


Figure 3



D_1, D_2 = distances indicated along the length of the lever arm.

Figure 4

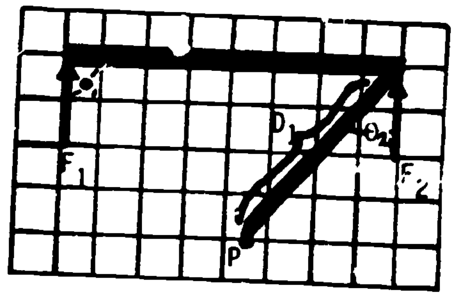
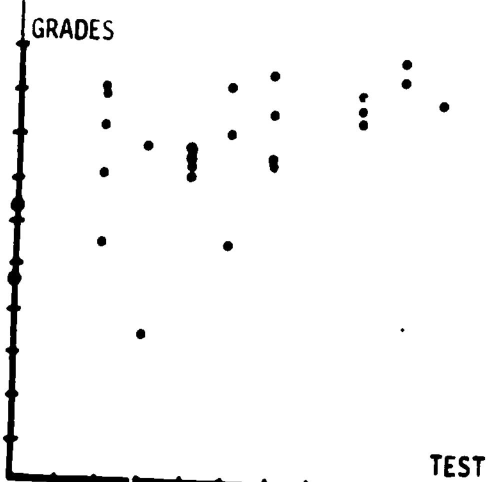


Figure 5

Figure 6



PROBLEM	# 4	# 7
% WRONG (TEST)	62 %	42 %
% WRONG (INT.)	66 %	0%

Table 1